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(71) Applicant
Standard Telephones and Cables Public Limited Company, (United Kingdom),
190, The Strand, London, WC2R 1DU

(72) Inventor
Peter John Dyke

(74) Agent and/or address for service
M. C. Dennis; S T C Patent Department, Edinburgh Way, Harlow, Essex, CM20 2SH

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Bell System Technical Journal January 1962 pages 25—97 (NB pages 78—83)

(58) Field of search
G1U

(54) Testing PCM Transmission Systems

(57) The operating margins of existing PCM transmission systems (e.g. 2 Mbit) operating on twisted pair cables, and an indication of the number of additional systems which can be added, is found using TRIOS signals (Figs. 4a, 4b) by detecting erroneous pulses after passage through the system, and increasing the TRIOS density until correlation ceases to a defined degree (Fig. 4c) to give an indication of the operating margins. Fig. 5 shows a device for comparing the transmitted signal with a local signal for detecting errors.

Fig4a. Trios signal 1 in 16 density

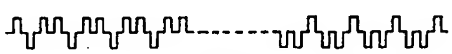


Fig.4b. Trios signal 1 in 3 density

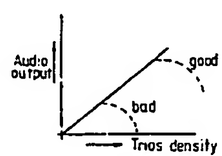


Fig.4c.

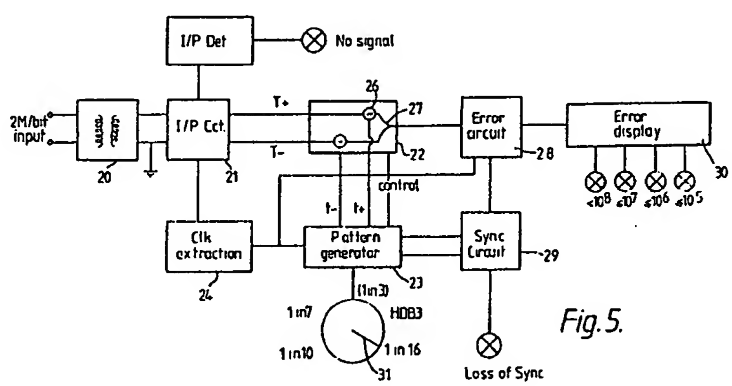


Fig.5.

The drawings originally filed were informal and the print here reproduced is taken form a later filed formal copy.
The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.
This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1982.

GB 2 138 575 A

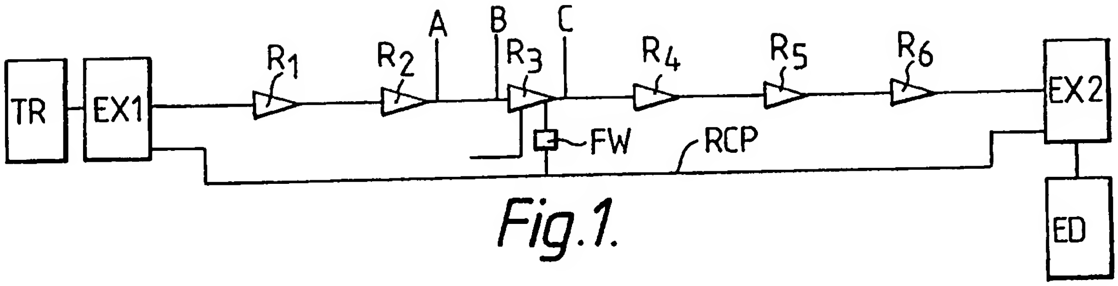


Fig.1.

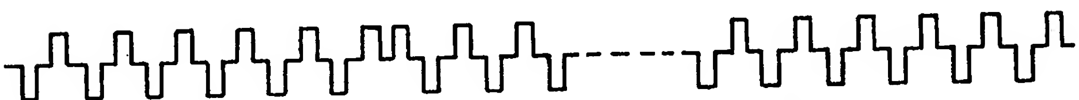


Fig.4a.

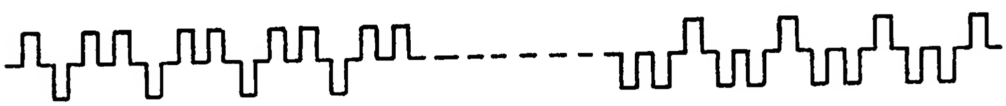


Fig.4b.

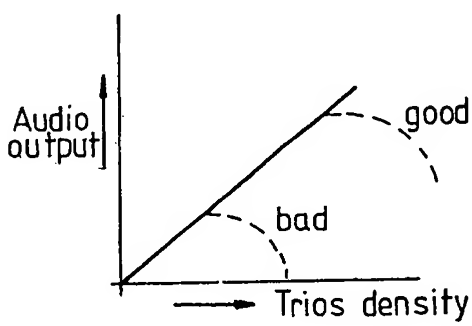
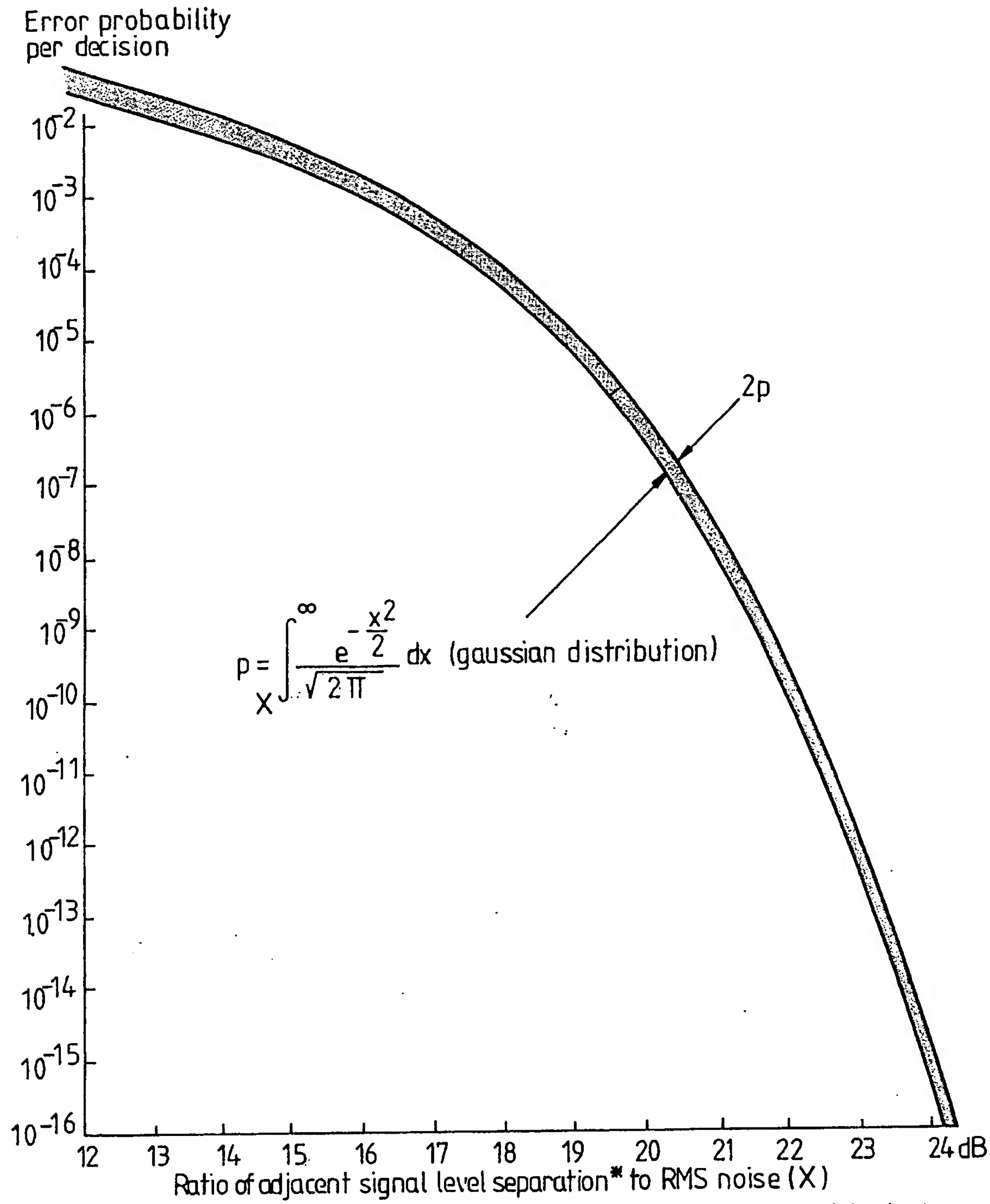


Fig.4c.



* eg. minimum symbol separation=peak-peak signal for binary= peak signal for tertiary

Error probability vs signal-to-noise ratio for added gaussian noise

Fig. 2.

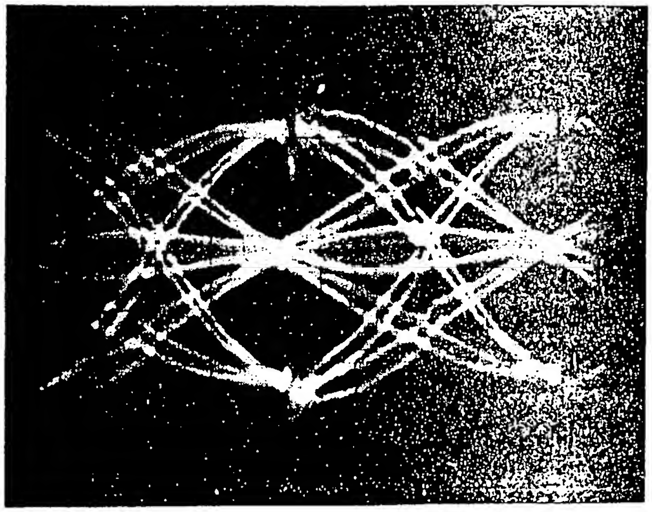


Fig.3a.

HDB3 with no Trios

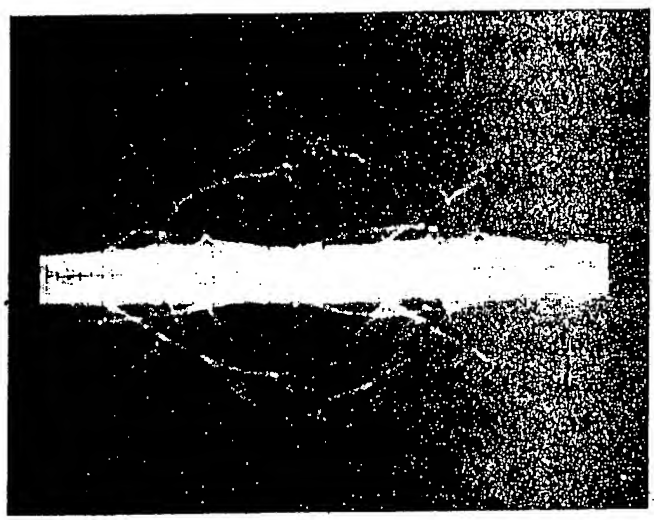


Fig.3b.

HDB3 with low density Trios (1 in 11)

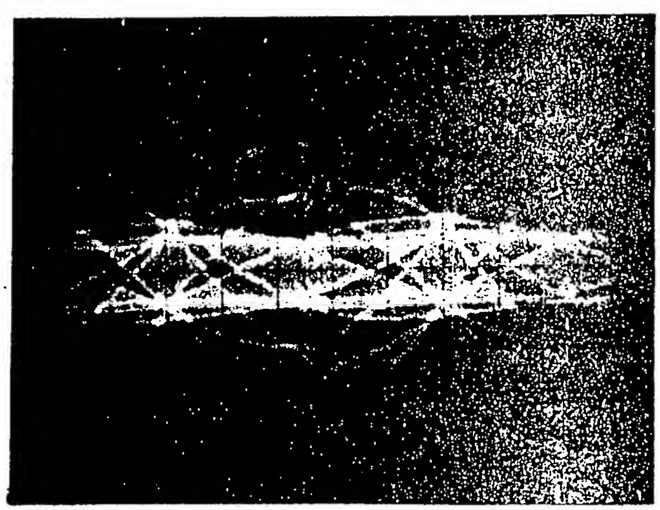


Fig.3c.

HDB3 with higher density Trios (1 in9)

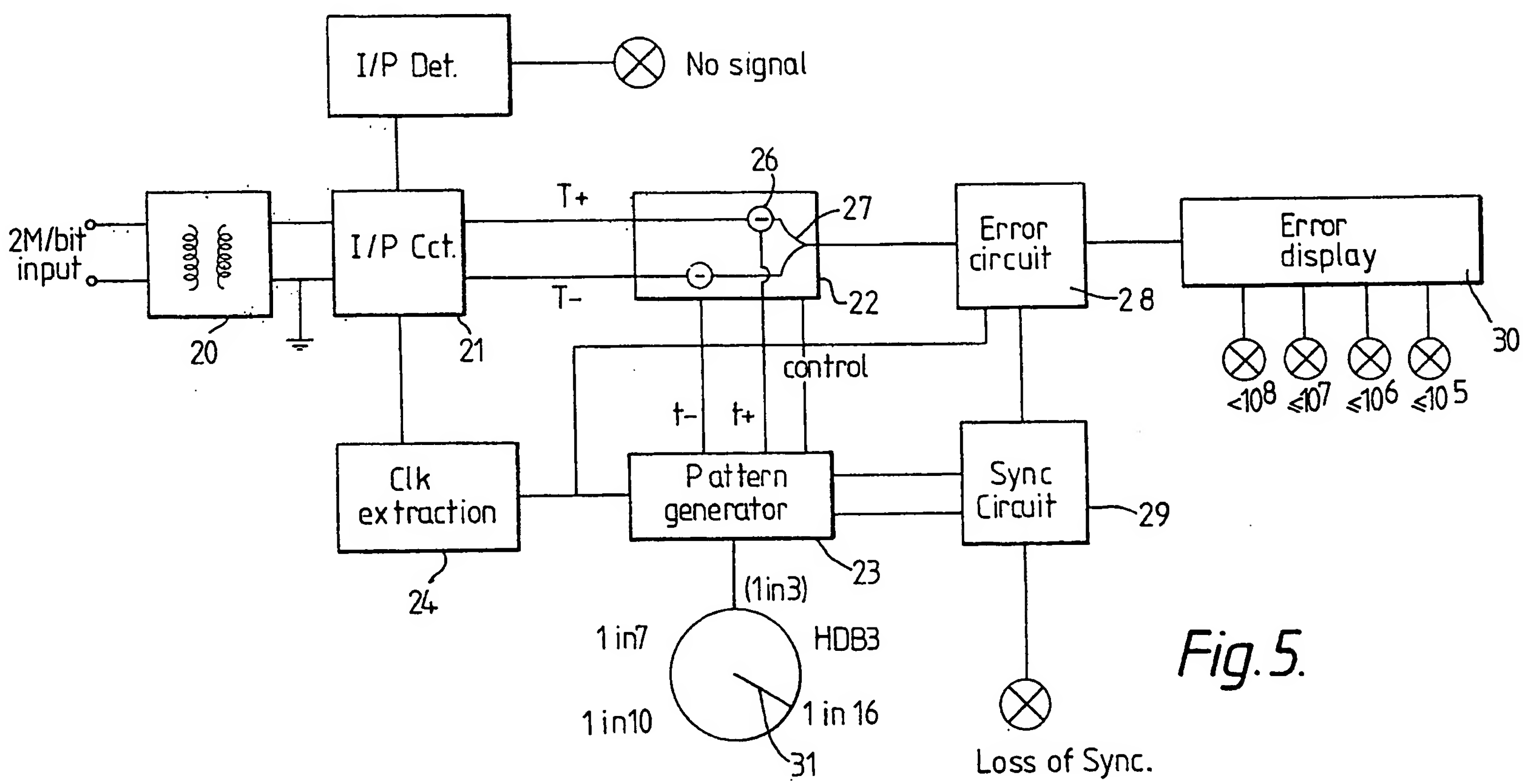

I/P Det.
No signal
2M/bit input
20
I/P Cct.
21
T+
T-
26
27
22
Error circuit
28
Error display
30
<10⁸
≤10⁷
≤10⁶
≤10⁵
control
t-
t+
Clk extraction
24
Pattern generator
23
Sync Circuit
29
(1in3)
1 in7
HDB3
1 in10
1 in 16
31
Loss of Sync.

Fig. 5.

SPECIFICATION

Testing PCM Transmission Systems

This invention relates to estimating or measuring the operating margin of PCM transmission systems which operate on twisted pair metallic cables.

When commissioning PCM transmission systems using balanced pairs, a quick and accurate assessment of the system's operating margin is required, for example an error rate of no more than 1 in 10^6 or even 1 in 10^8 is required. At present one method of measuring the operating margin requires tests to be made at individual locations along a PCM transmission route. Special test equipment is connected to a particular repeater section, which may be in a manhole. Referring to Figure 1 of the drawings there is shown diagrammatically a typical PCM repeatered route between two exchanges Ex1 and Ex2. Connections have to be made to points A, B, and C. A special card extender is used which is plugged into the housing at points A and B in order to modify the transmit signal at point A and the received signal at point B. Point C is monitored.

This requires a lot of effort in man hours. For example access to manholes is inconvenient. Also it requires assumptions to be made to "guess" which is the worst section requiring testing in any particular route. This is often assumed to be the longest section but this is not necessarily always the case. The proximity of power or other cables on a much shorter length could equally cause a lower margin than required.

Constant increase in traffic demands requires increasing use of existing cables and this tends to decrease the operating margin of existing installed systems. For example there may be ten systems on the particular route illustrated in Figure 1, with a cable having one hundred pairs, each system providing thirty PCM channels, and it is intended to add another such system, making eleven. It is necessary beforehand to establish if the operating margin of the existing systems will withstand the addition of yet another system or whether it will decrease that margin to an unacceptable level. For example if the existing systems have a 10 or 20 dB margin then there may be no problem in adding another system or even several systems. If however the excess margin is only 1 or 2 dB then it may not be satisfactory to add another system to that route.

Another way of estimating the existing system performance is to connect an error detector (not shown) to one end of the system, say at Exchange Ex2 and see what the error rate is over two or three days. It is possible to work from that error rate and calculate the ratio of peak signal to rms noise. There is a well defined curve, shown in Figure 2, from which we can predict the error rate with increased traffic based on the signal to noise ratio existing and on the assumption that the cause of the errors is say crosstalk, i.e. an assumption has to be made as to the nature of the interference that is causing the errors.

Although discrete states may be recognised in the presence of more noise and distortion than would be acceptable for an analogue signal, there is a probability that the noise will occasionally cause the threshold detection to recognise the signal state incorrectly and so produce an erroneous output pulse. This probability is shown in Figure 2 for noise with amplitude following a gaussian (normal) probability distribution. It applies to the usual circumstances where there are a large number of noise contributions of similar magnitude. Figure 2 is plotted in terms of level separation, i.e. amplitude difference between adjacent signal states at a decision instant, and assumes the thresholds are placed midway for good noise immunity. The lower and upper limits of the plot apply to the two extremes of binary or many-level signals respectively: in the latter case the probability is doubled because most signal states can be misinterpreted due to noise peaks of either polarity. In the use of Figure 2 allowances should be made for signal distortion and other impairments. Service requirements imply an error probability of 10^{-5} or even lower, where the slope in Figure 2 is already steep. This illustrates one of the most important features of a digital transmission system: the overall performance is critically dependent on worst case conditions and if errors occur in the system they are likely to come predominantly from one repeater. This leads naturally to great emphasis on establishing the system margin to errors.

It would not be possible to account for e.g. impulsive noise using this particular curve as there would be a number of different curves depending on the nature of the noise, and so it would be speculative to choose one particular curve and base a prediction on that. The IEE Conference Publication No. 193 Telecommunication Transmission entitled "Design and Assessment of Primary PCM Line Repeaters" by R. J. Catchpole and P. J. Dyke could with advantage be referred to.

A known method of fault location is based on the use of a TRIOS generator at an exchange or power feeding point. This provides a stream of pulses which are imbalanced over a defined period of time designed to close the eye of the PCM signal received at the repeater decision point, shown for example in Figures 3a, 3b and 3c.

The TRIOS signal shown in Figure 4a and Figure 4b is a combination of positive and negative pulses which differs from the HDB3 code normally adopted for e.g. a 2 Mbit/s route by changing the balance of the transmitted bipolar pattern, and this creates an audio frequency modulated on the 2 Mbit/s pattern which is monitored, via fault windings FW and a return cable pair, RCP, shown in Figure 1.

Basically the signal is shown in Figures 4a and 4b and comprises a series of positive and negative pulses, more positive than negative, followed by another series, more negative pulses

than positive pulses. The more positive series is alternated with the more negative series in the TRIOS generator to create the audio component and tuned to correspond to one of the fault locating filters.

The TRIOS pattern can be tuned so that the unique audio filter corresponding to a particular repeater housing will pass that audio signal back to the TRIOS generator so that a repeater or part of a repeater can be tested. The audio range available is normally 1 KHz to 10 KHz.

The TRIOS signal and its analysis can be understood more easily with reference to the Bell System Technical Journal, January 1962, pages 78 to 83.

The density of the TRIOS is then increased by increasing the number of positive and negative pulses respectively, which increases the amplitude of the audio tone. The return signal should be proportional to the unipolar density up to the point of a repeater failure. Eventually the signal received back via the return cable pair RCP, "crashes", indicating that the eye illustrated in Figures 3a to 3c has closed and the repeater has started making errors. By drawing a graph of audio output versus TRIOS density (Figure 4c) one can derive an indication of the margin for that particular repeater. The graph is basically a straight line until the "crash" occurs, and the longer the straight line the greater the margin.

This procedure is then repeated for each repeater filter frequency in turn by changing the period of series of TRIOS pulses, so that eventually the weakest link in the route can be determined.

There are PCM systems in which the repeaters have violation detectors which work under normal traffic conditions. These can be addressed from the exchange using a microprocessor and e.g. F.S.K. signalling. A particular error detector can be switched on and assigned to a particular repeater along the route and the errors can be directed back to the exchange. Thus each site along the route can be checked. However this arrangement has so far been installed in limited numbers. For the vast majority of existing systems such facilities are not available and it is for these systems that the present invention is intended to be applied.

It is an object of the present invention to enable the operating margin of existing systems on a route to be quickly and easily established from the exchanges. It can also give an indication of the number of additional systems which could safely be added to existing pairs.

According to the present invention there is provided a method of testing or measuring the operating margin of a bipolar PCM transmission system comprising:—

a) transmitting through the system a signal comprising a sequence of pulses having half cycles with unipolar density greater than zero;

b) detecting erroneous pulses in the sequence after passage through the system, e.g. by correlating individual pulses with individual locally generated pulses corresponding to those as sent;

c) increasing the unipolar density of the transmitted signal (and the locally generated pulses where appropriate) until correlation ceases; and

d) establishing the imbalance at which correlation ceases to a defined degree, whereby to give an indication of the system operating margin.

It would be possible as well as receiving an indication of the overall system margin, to have individual indications from each repeater in turn, as described previously, via a return cable pair connected to the fault winding of each repeater.

According to another aspect of the invention there is provided testing apparatus for testing or measuring the operating margin of a bipolar PCM transmission system in which there is transmitted through the system a signal comprising a sequence of pulses having half cycles with a unipolar density greater than zero, the apparatus comprising: means for detecting erroneous pulses in the sequence after passing through the system preferably by correlating individual pulses with individual locally generated pulses corresponding to those as sent, and means for increasing the unipolar density of the locally generated pulses in dependence upon a corresponding increase in density of the transmitted signal to establish the imbalance at which correlation ceases to a defined degree.

One exchange may transmit and the reception and correlation is done at the other exchange, or other convenient sites or loop-back arrangements are possible.

Preferably the unipolar density is greater than zero and less than zero in alternate half cycles.

Preferably also the received signal after passage through the system is passed through a bipolar to a unipolar convertor whereby positive and negative unipolar pulses appear in seperate channels and are respectively compared with locally generated positive and negative pulses.

In order that the invention can be clearly understood reference will now be made to the accompanying drawings in which:—

Figure 1 shows a block diagram of a PCM transmission system with testing apparatus for testing the operating margin according to an embodiment of the invention;

Figure 2 is a graph showing the theoretical error rate for Gaussian noise against signal-to-noise ratio for the system of Figure 1;

Figures 3a to 3c are pictures of the PCM signal "eye" at the point C in Figure 1 for three different intensities of TRIOS signal modulated on it, Figure 3c showing the "eye" just closed;

Figures 4a and 4b show typical TRIOS signals of density 1 in 16 and 1 in 3 respectively;

Figure 4c is a graph of audio output versus TRIOS density; and

Figure 5 shows a block diagram of a PCM margin tester for primary line repeatered spans suitable for use as the error detector ED in Figure 1.

Referring to Figure 1 a 2 Mbit/s route is shown diagrammatically extending between two exchanges Ex1 and Ex2. 2 Mbit/s HDB3 systems are used in the description below, although the invention applies to other rates and coding. Six repeaters R1 to R6 are shown for the traffic direction Ex1 to Ex2, but this shows only one side of each two-way repeater and a transmission direction from Ex2 to Ex1 exists through the other side of the repeaters. Other aspects of the system have been described already.

A TRIOS generator TR is connected to the system at exchange Ex1 while the system is out of traffic and a TRIOS error detector ED is connected at the receive end Ex2. Details of the error detector ED are described later with reference to Figure 5. The TRIOS generator TR and error detector ED can be synchronised by sending a very low-density TRIOS signal to start with to obtain synchronism without errors occurring and progressively increasing the density in step by step manner with a corresponding switching of the error detector for corresponding density TRIOS signals so the transmitted receiver remain synchronised. The error detector ED can, but not necessarily does, work by looking at each individual pulse transmitted and comparing it with each received pulse i.e. a bit by bit comparison. If it receives bits not transmitted or does not receive bits which are transmitted then it can indicate each error occurring.

Referring now to Figure 5 the error detector comprises an input transformer 20 which receives the PCM signal, in this case assumed to be a 2 Mbit/s input, as a bipolar balanced signal. This feeds an input circuit 21 which acts as a bipolar-to-unipolar converter to separate unbalanced positive pulses and negative pulses created by the TRIOS signal and put then onto separate channels T+ and T—. These pulses are fed to comparators in a comparator circuit 22. These comparators compare the positive and negative pulses t+ and t— generated by a pattern generator 23 with the pulses T+ and T— derived from the TRIOS signal modulated on the 2 Mbit/s signal and a pulse-by-pulse comparison takes place. The pattern generator 23 is synchronised with the PCM signal by a clock extraction circuit 24 which extracts a clock signal based on the 2 Mbit/s signal from the input circuit.

The comparator comprises a pair of exclusive-OR gates 25 and 26 followed by a combining OR gate 27. The output from the comparator is fed to an error counter 28 controlled from the clock extraction circuit by the line "control". This enables error ratios or rates to be computed. Also synchronisation of the received TRIOS signal with the pattern generator is achieved through a synchronisation circuit 29.

Every time the T+ and t+ or T— and t— signals disagree the error counter registers the error and provides a signal to an error display circuit 30 which displays an error rate by illuminating a lamp corresponding to particular error ratio, e.g. less than 10^8, less than or equal to 10^7 etc.

The pattern generator 23 can be switched by a manual switch 31 to change the TRIOS signal density to thus control the pattern of the pattern generator 23 accordingly. This is done in synchronism with an identical switch on the TRIOS generator at exchange Ex1. Two people, one at one exchange and one at the other who are in separate communication with each other would operate the testing apparatus. Alternatively the testing procedure could be automated by computer control.

The test procedure commences with a 1 in 16 TRIOS signal i.e. low density and the modulation would be slight so that the eye of the PCM signal would be similar to that shown in Figure 3a. The frequency of the signal would be in the audio range 1 KHz to 10 KHz, although other frequencies would be possible, e.g. higher frequencies, provided only the frequency differed significantly from the bit rate of the system, in this example 2 Mbit/s. The 1 in 16 density signal from the TRIOS generator corresponds to the position of the manual switch 31 shown in Figure 5. The switches on both transmit and receive equipment is then changed to 1 in 10, and so on until an error rate is displayed by the error display 30.

In Figure 3b the TRIOS density is 1 in 11 and in Figure 3c it is 1 in 9. Complete closure of the eye would occur at a TRIOS density of 1 in 7 or 1 in 3, depending on the repeater design realisation and noise conditions and the point at which correlation ceases as noted from the display. At that point the amount of closure of the eye is known from the density being sent, and it is possible to work out the margin lost by putting this density signal on the system.

CLAIMS

1. A method of testing or measuring the operating margin of a bipolar PCM transmission system comprising:—

a) transmitting through the system a signal comprising a sequence of pulses having half cycles with unipolar density greater than zero;

b) detecting erroneous pulses in the sequence after passage through the system, e.g. by correlating individual pulses with individual locally generated pulses corresponding to those as sent;

c) increasing the unipolar density of the transmitted signal (and the locally generated pulses where appropriate) until exact correlation ceases; and

d) establishing the imbalance at which correlation ceases to a defined degree, whereby to give an indication of the system operating margin.

2. A method as claimed in claim 1, wherein